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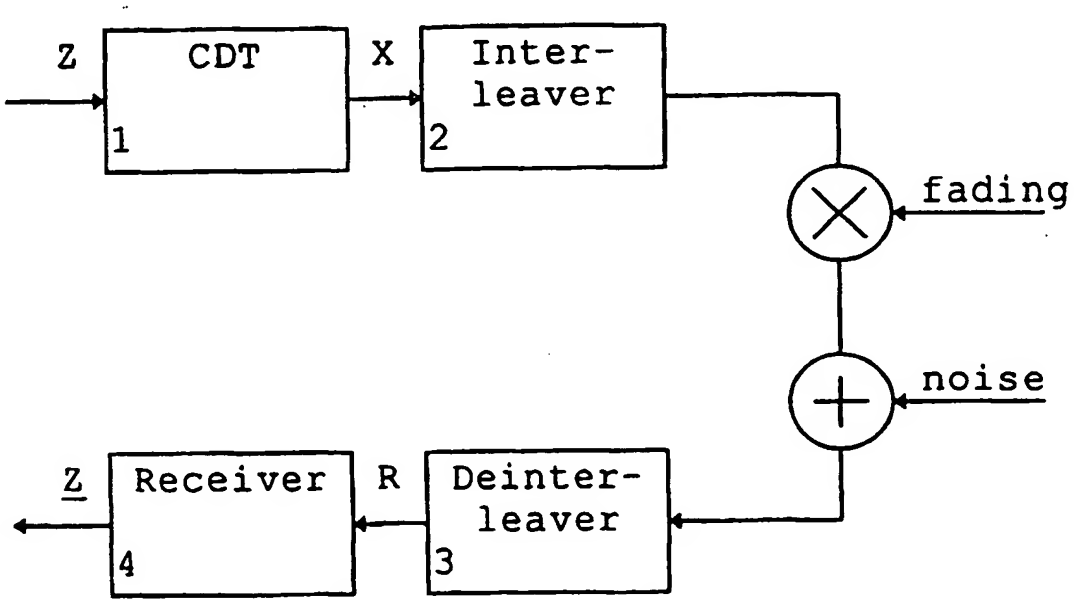
(54) Title: DIVERSITY TRANSMISSION METHOD AND SYSTEM



(57) Abstract: The present invention relates to a diversity transmission method and system, wherein a transmission signal is divided into a plurality of subsignals. A first set of the subsignals in transmitted using a first diversity transmission scheme, and a second set of said subsignals is transmitted using a second diversity transmission scheme. Thus, a joint coordination between different types of diversity transmission schemes is proposed so as to achieve a significant capacity increase at a moderate complexity.

WO 00/79701 A1

DIVERSITY TRANSMISSION METHOD AND SYSTEM

FIELD OF THE INVENTION

The present invention relates to a diversity transmission method and system for transmitting a transmission signal in a wireless communication system, such as the Universal Mobile Telecommunications System (UMTS).

BACKGROUND OF THE INVENTION

Wideband Code Division Multiple Access (WCDMA) has been chosen as the radio technology for the paired bands of the UMTS. Consequently, WCDMA is the common radio technology standard for third-generation wide-area mobile communications. WCDMA has been designed for high-data services and, more particularly, Internet-based packet-data offering up to 2 Mbps in indoor environments and over 384 kbps for wide-area applications.

The WCDMA concept is based on a new general structure for all layers built on technologies such as packet-data channels and service multiplexing. The new concept also includes pilot symbols and a time-slotted structure which has led to the provision of adaptive antenna arrays which direct antenna beams at users to provide maximum range and minimum interference. This is also crucial when implementing wideband technology where limited radio spectrum is available.

The uplink capacity of the proposed WCDMA systems can be enhanced by various techniques including multi-antenna reception and multi-user detection or interference

cancellation. Techniques that increase the downlink capacity have not been developed with the same intensity. However, the capacity demand due to the projected data services (e.g. Internet) burdens more heavily the downlink channel. Hence, it is important to find techniques that improve the capacity of the downlink channel.

Bearing in mind the strict complexity requirements of terminals, and the characteristics of the downlink channel, the provision of multiple receive antennas is not a desired solution to the downlink capacity problem. Therefore, alternative solutions have been proposed suggesting that multiple antennas or transmit diversity at the base station will increase downlink capacity with minor increase of complexity in terminal implementation.

In third-generation mobile radio systems in general and in particular for WCDMA systems, the downlink capacity is a bottleneck. This is due to fading of the transmitted signal, wherein the amplitude of the signal is subjected to random fluctuations. To overcome this situation, transmitter antenna diversity has been proposed for the downlink direction. Known transmitter diversities schemes can be divided into two categories, open loop systems and closed loop systems. The difference between the open loop and the closed loop systems is that the former sends a feedforward or training information, in order to provide an information about the channel at the receiver. On the other hand, the latter system gets knowledge of the channel at the transmitter side by virtue of a feedback path from the receiver to the transmitter. Selective Transmit Diversity (STD) is an example of a closed loop system which is easy to implement in digital cellular systems due to the presence of a permanent feedback connection. Furthermore,

systems that employ either of the two categories of transmitter diversity are known.

The prior art diversity systems are described e.g. in document US-A-5,832,044 and in the publications "Fading Resistant Modulation Using Several Transmitter Antennas" by Sousa et al., IEEE Trans. On Communications, p.p. 1236-1244, Oct. 1997, and "Diversity Transform for Fading Channels", by D. Rainish, IEEE Trans. On Communications, p.p. 1653-1661, Dec. 1996.

In the above prior art systems, all components of a constellation vector (super symbol) are transmitted via either of different antennas, different carrier frequencies, or diferent time slots. However, since the optimum decoding complexity grows exponentially with the number of components of the constellation vector, the transmission capacity is limited. Moreover, a high peak to average ratio results from an increased constellation size.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a diversity transmission method and system, by means of which the transmission capacity can be increased.

This object is achieved by a diversity transmission method for transmitting a transmission signal in a wireless communication system, comprising the steps of:
dividing the transmission signal into a plurality of subsignals;
applying an orthonormal transformation to said plurality of subsignals;

transmitting a first set of the subsignals using a first diversity transmission scheme; and
transmitting a second set of the subsignals using a second diversity transmission scheme, the second diversity transmission scheme being different from the first diversity transmission scheme.

Furthermore, the above object is achieved by a transmitter for a diversity transmission system for transmitting transmission signal in a wireless communication system, comprising:
dividing means for dividing the transmission signal into a plurality of subsignals; and
transforming means for applying an orthonormal transformation to said plurality of subsignals;
transmitting means for transmitting a first set of the subsignals using a first diversity transmission scheme, and a second set of the subsignals using a second diversity transmission scheme different from the first diversity transmission scheme.

Additionally, the above object is achieved by a receiver for a diversity transmission system, for receiving a transmission signal in a wireless communication system, comprising:
receiving means for receiving a transmission signal comprising a first set of subsignals transmitted by using a first diversity transmission scheme, and a second set of subsignals transmitted by using a second diversity transmission scheme different from the first diversity transmission scheme; and
decoding means for decoding the transmission signal by deciding on a maximum likelihood between the received subsignals and corresponding estimated subsignals.

Accordingly, a joint coordination between different diversity transmission types is provided, which results in a significant capacity increase as compared to previous transmitter diversity schemes based on multidimensional fading resistant constellations. Thus, an optimum detection method can be used which makes the optimum decoding complexity grow linear with the dimension of the constellations.

In a cellular network, a fading resistant transmission scheme can be provided, where a base station uses M antennas or/and M time slots (regardless of the use a frame orientated power control) or/and M carrier frequencies (for narrow band systems), wherein M denotes the dimension of the signal constellation.

Preferably, the first diversity transmission scheme is a space diversity transmission scheme, such as a selective transmitter antenna diversity (STD). The second diversity transmission scheme may be a frequency or time diversity scheme. The original signal constellation may be represented as a matrix, wherein each row of the matrix corresponds to a point in a multidimensional constellation. In particular, a complex diversity transformation may be used, wherein an orthonormal transformation to a constellation which preserves Euclidean distances but improves the resistance to fading may be performed. The orthonormal transformation may be achieved by a multiplication with a complex matrix. Preferably, each row of the complex matrix is orthogonal to any other row, wherein the determinant of the matrix is equal to one. The complex matrix may be obtained based on the upper bound on the symbol error rate or based on the cut off rate.

Preferably, the diversity transmission method is used in the downlink direction of a cellular network.

The transmission signal may be a bit stream and the plurality of subsignals may be substreams. In particular, the transmission signal may be a PSK signal, preferably a QPSK signal which can be represented by a vertex in a 2M-dimensional hyper-cube, where M denotes the dimension of the signal constellation. In this case, the receiving means may comprise a bank of 2M correlators, wherein M denotes the number of transmission antennas used in the first diversity transmission scheme.

The wireless communication system may be a WCDMA system, wherein the transmitter may be arranged in a WCDMA base station and the receiver in a WCDMA mobile station.

Furthermore, the first and second diversity transmission schemes may comprise an open loop and/or a closed loop system.

Preferably, time slots of frequency carriers used in the second diversity transmission scheme are spaced apart to such a degree that independent fading is assured. Thereby, the transmissions can be coordinated to mitigate the effects of multi-path Rayleigh fading, and the receiver can recover the entire M-dimensional transmitted signal constellation or vector, as long as the signal energy of at least one coordinate is large enough. In particular, the M-dimensional signal constellation may be generated by optimizing the bit error rate and the peak to average ratio for a Rayleigh fading channel. The bit-error-rate may be further improved by using the STD scheme. This scheme

offers a significant performance improvement over the conventional single antenna N-PSK scheme and other known M-dimensional fading resisting constellations for a given bit-error-rate. In the downlink direction of a cellular network, a significant capacity increase is achieved as compared to uncoded N-PSK and other known M-dimensional fading resistant constellations.

Preferably, the transmitting means comprises a complex diversity transformation unit arranged for performing an orthonormal transformation to a constellation which preserves Euclidean distances but improves resistance to fading of an original signal constellation obtained from the dividing means.

Furthermore, the receiver may comprise channel estimation means for performing a channel estimation used for obtaining the corresponding estimated subsignal.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the present invention will be described in greater detail on the basis of a preferred embodiment which reference to the accompanying drawings, in which:

Fig. 1 shows a principle block diagram of a transmission system according to the present invention,

Fig. 2 shows a principle block diagram of a transmitter according to a preferred embodiment of the present invention; and

Fig. 3 shows a principle block diagram of a receiver according to a preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following, the preferred embodiment of the present invention will be described on the basis of a downlink transmission between a base station and a mobile station of a cellular network such as the UMTS.

In spectrally efficient transmitter antenna, frequency and time diversity schemes, the information bit stream is divided into substreams, wherein each substream is transmitted over a different antenna, a different frequency, or a different time slot. Taking jointly, the transmission of a set of symbols can be viewed as the transmission of a super symbol. In the case of a QPSK transmission, the super symbol can be represented by a vertex in a 2M-dimensional hyper-cube, where M denotes the number of antennas, frequencies, or time slots.

According to the preferred embodiment of the present invention, a wideband system is considered such that the use of multiple carriers is not appropriate and will not be described in detail. However, the present invention is not restricted to wideband systems.

The WCDMA system operates at a low signal to noise ratio. Therefore, optimal signaling constellations for N-PSK modulations which are fading resistant at low signal to noise ratios are required.

The transmitter transmits a sequence of symbols from a fixed symbol alphabet. As already mentioned, each symbol may be represented as a vector in an M-dimensional vector space. Thus, each vector has M components. According to the present invention, the transmission of the M components is combined in different antennas and different time slots. Furthermore, in case of narrowband systems, a combination with different frequency carriers can be used for transmitting the M components. In particular, the constellation is obtained from an M-dimensional hyper-cube based on an orthogonal transformation. However, the separation between constellation points may be further maximized and none of the points are superimposed. The result is a much better performance over fading channels.

Fig. 1 shows a principle block diagram of the diversity transmission system according to a present invention. The system comprises M transmitter antennas (not shown) for transmitting a transmission signal from a base station to a mobile terminal, and a single receiver antenna (not shown). Thus, the received base band signal is obtained by the following equation:

$$r(t) = \sum_{i=1}^{M} x_i \, s_i(t) \sum_{j=1}^{L} (\alpha_i^j + n_i^j(t)) \qquad (1)$$

Between the receiver antenna and each transmitter antennas there are L multi-paths, wherein the symbol α_i^j denotes the Rayleigh fading of the j-th multi-path of the i-th transmit antenna at the receiver, x_i represents the N-PSK transformed signal on the i-th antenna, $s_i(t)$ denotes a bandlimited pulse, where $s_i(t)$, $s_k(t)$ are assumed to be

orthogonal for i ≠ k. similarly, $n_i^j(t)$ denotes the added AWGN (Additive Wide Gaussian Noise) with power spectral density No/2.

An independent fading can be assumed if the transmitter antennas or time slots of frequency carriers are sufficiently spaced apart.

According to the present invention, the receiver 4 is capable of estimating the fading amplitude of each link. This is possible, if the fading amplitudes vary slowly over time. If the fading amplitudes vary quickly over time, it is expected that the receiver performance degrades due to estimation errors.

In the transmitter, a complex diversity transformation unit 1 is provided for performing a diversity transformation of an input signal constellation set which can be represented as a matrix. The interleaver 2 and deinterleaver 3 shown in Fig. 1 are not specific to the diversity transformation. They relate to the usual interleaving required for systems with forward error correction capabilities. In such systems, it is necessary to assure that fading amplitudes are uncorrelated. The delay introduced by the interleaver depends on the giving service and the general fading characteristics.

The original signal constellation is represented as a matrix Z, where each row corresponds to a point in the M-dimensional constellation corresponding to M input (encoded) symbols. Given the M-dimensional constellation of $Q = N^M$ points, a transformation is applied by the complex diversity transformation unit 1, such that the Euclidean

distances between the constellation points are preserved, but the constellations resistance to fading is improved. The requirement that the transformation preserves the Euclidean distances between points and norms is imposed to thereby assure that the performance of the new constellation in the AWGN channel is not degraded. Such orthonormal transformations are called isometries.

For example, in case of a BPSK or a QPSK system, the original constellations for M = 2 are given by

$$Z_{BPSK} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ -1 & -1 \\ -1 & 1 \end{bmatrix}, \quad Z_{QPSK} = \begin{bmatrix} 1+j & 1+j \\ 1+j & 1-j \\ 1+j & -1-j \\ 1+j & -1+j \\ 1-j & 1+j \\ 1-j & 1-j \\ 1-j & -1-j \\ 1-j & -1+j \\ -1-j & 1+j \\ -1-j & 1-j \\ -1-j & -1-j \\ -1-j & -1+j \\ -1+j & 1+j \\ -1+j & 1-j \\ -1+j & -1-j \\ -1+j & -1+j \end{bmatrix}$$

These constellation matrixes are multiplied in the complex diversity transformation unit 1 by an orthonormal M x M matrix A_M to thereby preserve the distance between vectors, and the energy. The transformed constellation X is given by

$$X = ZA_M \qquad (2)$$

To be orthonormal, the complex matrix AM must fulfill the following conditions:

(1) each row is orthogonal to any other row;

(2) the determinant of the matrix is equal to one.

According to the invention, the orthonormal complex matrixes for M = 2 and M = 2^n are generally given by

$$\overline{A_2} = \frac{A_2}{|A_2|^{1/M}}, \quad A_2 = \begin{bmatrix} e^{j\phi} & e^{-j\phi} \\ -e^{-j\phi} & e^{j\phi} \end{bmatrix}, \quad |A_2| = \det(A_2) = 2\cos(2\phi)$$

$$\overline{A_{2n}} = \frac{A_{2n}}{|A_{2n}|^{1/M}}, \quad A_{2n} = \begin{bmatrix} A_n & A_n \\ A_n & -A_n \end{bmatrix}, \quad |A_{2n}| = \det(A_{2n}) = f(\phi) \tag{3}$$

wherein ϕ denotes the angle that must be chosen in order to minimize the error probability in fading channels. This, however, constitutes an untractable problem in mathematics. Therefore, two other suboptimal approaches can be used, i.e. the upperbound on the symbol error rate and the cutoff rate, wherein the vector is assumed to be part of a random code with infinite length in which all vectors are independent. The upperbound on the symbol error rate is described e.g. in "Introduction to Trellis-Coded Modulation with Applications" by E. Biglieri et al., Macmillan Pub., 1993, chapter 9, and is given by

$$P(\mathbf{x} \rightarrow \underline{\mathbf{x}}) = \operatorname{Min}_{x \neq \underline{x}} \forall(x,\underline{x}) \prod_{i=1}^{M} \frac{1}{1 + \frac{E_S}{4N_0}|x_i - \underline{x_i}|^2} \tag{4}$$

and the cutoff rate is described e.g. in "Diversity Transform for Fading Channels" by D. Rainish, IEEE

Transaction On Communications, p.p. 1653-1661, Dec. 1996. and is given by

$$R_0 = \log_2 N - \frac{1}{M}\log_2 \left[\forall(x,\underline{x}) \prod_{x \neq \underline{x}}^{M} \frac{1}{1+\frac{E_s}{4N_0}\left|x_i - \underline{x_i}\right|^2} \right] \qquad (5)$$

wherein N denotes the dimension of the modulation, e.g. N = 4 for QPSK modulation.

Comparing the two above equations (4) and (5) it can be seen that they are somehow related. The main difference lies in the minimum operator only used in the bit error rate upperbound. This criteria is optimum for a use of the scheme in a high signal to noise ratio environment. In this invention, however, the interesting signal to noise ratio (SNR) comprises small values of E_s/N_0. Thus, the cutoff rate is preferably chosen, because it considers all pairs of $(\mathbf{x},\underline{\mathbf{x}})$, wherein $\mathbf{x}$ indicates the transmitted vector and $\underline{\mathbf{x}}$ denotes the super symbol picked up in the receiver 4. There are certain values of ϕ which cannot be used. Those values must be avoided. For N-PSK modulations, the acceptable angles are defined by

$$\phi \neq \pi/N \ , \ \phi < \pi/N \qquad (6)$$

To be fading resistant, any two points of the signal constellation should have a large number of components which differ significantly. For every M and in particular for M = 2, it is important that the determinant of the complex matrix A_M is minimized, such that a large number of components differ significantly and a better performance of

the scheme is achieved. However, to obtain low determinant values, the limit given by equation (6) must be approached, which originates signaling constellation points close to zero and high peak to average amplitude ratios. The search for an optimal angle ϕ can be made exhaustively for small discredisation intervals, e.g. 1°, because only one angle has to be optimized. The optimal interval for the angle ϕ is $[\pi/8, \pi/6]$. In the preferred embodiment, an angle $\phi = \pi/6$ has been chosen. For this angle, the determinant of the complex matrix A_2 is equal to one.

In general, the performance results obtained by a complex orthogonal matrix are better than those obtained by a real orthonormal matrix for M = 2 and M = 4.

According to the preferred embodiment of the present invention, a selective transmitter antenna diversity (STD) is combined with the complex diversity transformation (CDT). Thereby, a diversity of any order can be obtained. For instance, a diversity of order 8 can be obtained e.g. by using a complex diversity transformation of order 4 (time diversity) and an STD with 2 antennas, or by using a complex diversity transformation of order 2 and a STD diversity with 4 antennas.

Fig. 2 shows a principal block diagram of a transmitter which may be used in a base station and in which a combined CDT and STD are performed. According to Fig. 2 the transmitter comprises a coding unit 10 arranged for generating the signal constellation matrix Z based on received input symbols to be transmitted to a mobile station. The generated constellation matrix Z is supplied to a complex diversity transformation unit 11 which

performs a multiplication of the constellation matrix Z with the orthonormal matrix A_M, as defined in the equation (2). In particular, the coding unit 10 and the complex diversity transformation unit 11 may be realized by corresponding digital processing circuits or by a central processing unit controlled on the basis of a corresponding control program. The obtained transformed signal constellation matrix X is supplied to a transmitting unit Tx 12, wherein each column of the transformed constellation matrix X corresponds to a respective one of a plurality of transmission antennas A1, A2,...AM, such that a first set of subsignals or subsymbols (correspoonding to the matrix columns) are transmitted via respective different ones of the transmission antennas A1 to AM, and a second set of subsignals or subsymbols (corresponding to matrix rows) are transmitted in respective different time slots.

Fig. 3 shows a corresponding receiver of the transmission system, which may be provided in a mobile station of a cellular network. In the present case, a QPSK modulation is used for the transmission, wherein the receiver is a QPSK optimum receiver consisting of a bank of 2M integrators (or correlators) 4110, 4111, 4120, 4121,...41M0, 41M1.

The radio signals transmitted from the transmission antennas A1 to AM are received via a single receiving antenna by a receiving unit Rx 40 of the receiver, and an in-phase component and a quadrature component are obtained by multiplying the received signal with a sine signal and a cosine signal, respectively, of the carrier frequency. The in-phase and quadrature components are each supplied to M processing channels, where a detection is performed based on a multiplication with respective bandlimited pulse

signals $s_1(t)$, $s_2(t)$, ...$s_M(t)$. The detected received signals are supplied to respective ones of the integrators 4110 to 41M1. In the present preferred embodiment, only coherent demodulators are considered. For a single path Rayleigh fading channel (L = 1, subscript j dropped), the output of the i-th integrator (correlator) is given by

$$y_i = \int_0^T r(t)s_i(t)dt = \alpha_i x_i E_S + \eta_i, \quad E_S = \int_0^T s_i^2(t)dt \tag{7}$$

wherein η_i ($1 \leq i \leq M$) denotes an uncorrelated zero-mean Gaussian random variable with variance N_0E_S, and wherein T denotes the time period of a received symbol. Thus, most of the energy of the signal $s_i(t)$ is contained in the interval [0, T].

The outputs of the integrators 4110, 4120,..., 41M0 of the in-phase component and the integrators 4111, 4121,..., 41M1 of the quadrature component are combined by respective combining circuits 421 to 42M which output the components y_1 to y_M of the received vector $\mathbf{y}$. The received vector $\mathbf{y} = (y_1,...y_M)$ is supplied to a decision device such as a minimum distance decoder 43 which estimates the transmitted vector $\mathbf{x} = (x_1,...x_M)$. Furthermore, a channel estimator 44 is provided for estimating fading amplitudes α_i and for supplying the estimated fading amplitudes α_i to the minimum distance decoder 43. The minimum distance decoder 43 selects a super symbol $\underline{\mathbf{x}} = (\underline{x}_1,...\underline{x}_M)$ which is an element of an M-dimensional constellation. The selection is performed in such a manner that the following equation is satisfied

$$Min \sum_{i=1}^{M} \left| y_i / E_S - \alpha_i \underline{x} \right|^2, \quad \forall (x, \underline{x}) \tag{8}$$

A symbol detecting error occurs, when $\mathbf{x} \neq \underline{\mathbf{x}}$. Thus, the receiver is a maximum likelihood receiver arranged to choose between N^M (N is the size of the alphabet) possible different combinations of $(\mathbf{x}, \underline{\mathbf{x}})$.

The communication links between the transmitting antennas A1 to AM and the receiving antenna are not generally line-of-sight links. In general, a multi-path Rayleigh fading model is assumed. The fading amplitudes α_i^j are modelled as independent and identically distributed Rayleigh random variables, wherein the probability density function is given by

$$f(\alpha) = 2\alpha \exp(-\alpha^2), \quad \alpha \geq 0 \tag{9}$$

It is to be noted that the interleaver 2 and the deinterleaver 3 shown in Fig. 1 and required for forward error correction capabilities are not shown in the transmitter and the receiver according to Figs. 2 and 3, respectively.

The present invention is not restricted to a combination of CDT with STD. Any combination of different diversity schemes can be used, wherein a combination of a space diversity scheme such as STD with time diversity schemes such as CDT, RDT (Real Diversity Transformation), may be applied.

The reference probability of the bit error rate for uncoded wideband systems is $P_b = 4 \times 10^{-2}$. For this reference P_b, a gain of 2dB can be achieved between CDT and RDT without STD. If STD is combined with other diversity transformations, a gain of 1.5 dB is achieved between CDT and RDT. Compared to a single STD, the combination of CDT with STD provides an additional gain of 2.1 dB. For all diversity transformations, an optimal angle $\phi = \pi/6$ has been obtained.

For higher diversity orders, such as M = 4, CDT continues to provide additional gain over RDT with and without STD, however, now these gains are not so significant. When CDT (with diversity order 2) and STD (with diversity order 2) are combined, the equivalent diversity order is 4. Another way to achieve this diversity order is CDT with diversity order 4. The comparison between these two cases indicates that CDT + STD leads to a better performance and should therefore be chosen.

The minimum distance decoder 43 shown in Fig. 3 is able to avoid the exponential growth of the decoding complexity, when the minimum distance is chosen between $(\mathbf{x}, \underline{\mathbf{x}})$, as given by equation (8). This can be gathered from the following equation

$$\left|y_1/E_s - \alpha_1 \underline{x}_1\right|^2, \forall(x_1, \underline{x}_1) \cdot\cdot \left|y_2/E_s - \alpha_2 \underline{x}_2\right|^2, \forall(x_2, \underline{x}_2) \cdot\cdot\cdot \left|y_M/E_s - \alpha_M \underline{x}_M\right|^2, \forall(x_M, \underline{x}_M) \qquad (10)$$

Since the metrics is positive and additive, it is better to compute the minimum distance individually for each link i and decide individually on the transmitted symbols.

As an example, a 4-PSK signal with diversity order M = 4 is considered. Based on the equation (10) the following result is obtained.

$$d_1=|y_1/E_S-a_1(1+j)|^2, d_2=|y_1/E_S-a_1(1-j)|^2, d_3=|y_1/E_S-a_1(-1-j)|^2, d_4=|y_1/E_S-a_1(-1+j)|^2 \qquad (11)$$

Accordingly, the minimum is chosen for all $d_n (1 \leq n \leq N)$, which leads to the decision on x_1. Next, the decision is made as to x_2, based on the minimum of N metrics, and so on, until a decision is made on x_M, also based on N metrics, wherein N = 4. Thus, M decisions are performed based on N metrics. Thus, N x M metrics have to be computed, instead of N^M as in the known solutions.

The present inventions can be implemented in a variety of ways. A combination of spectrally efficient transmitter time diversity of order M_1 with a selective transmitter antenna diversity (STD) of order M_2 is preferred to achieve a total diversity order of $M = M_1 \times M_2$. For narrowband systems, the present invention can be implemented as a spectrally efficient transmitter frequency diversity scheme in combination with STD, so as to increase the order of the diversity.

The present invention can be applied to improve the performance of the physical layer of the UMTS UTRA/FDD (UMTS Radio Access/Frequency Division Duplex) components. Alternatively, it may be implemented in the physical layer of UMTS UTRA/TDD (Time Division Duplex) components. In general, the present invention can be implemented in any transmission link of any digital cellular network to

thereby increase the capacity of that link. Therefore, the above description of the preferred embodiment and the accompanying drawings are only intended to illustrate the present invention. The preferred embodiment of the invention may vary within the scope of the attached claims.

In summary, the present invention relates to a diversity transmission method and system, wherein a transmission signal is divided into a plurality of subsignals. A first set of the subsignals is transmitted using a first diversity transmission scheme, and a second set of the subsignals is transmitted using a second diversity transmission scheme. Thus, a joint coordination between different types of diversity transmission schemes is proposed so as to achieve a significant capacity increase at a moderate complexity.

Claims

1. A diversity transmission method for transmitting a transmission signal in a wireless communication system, comprising the steps of:

a) dividing said transmission signal into a plurality of subsignals;

b) applying an orthonormal transformation to said plurality of subsignals;

c) transmitting a first set of subsignals using a first diversity transmission scheme; and

d) transmitting a second set of said subsignals using a second diversity transmission scheme, said second diversity transmission scheme being different form said first diversity transmission scheme.

2. A method according to claim 1, wherein said first diversity transmission scheme is a space diversity transmission scheme.

3. A method according to claim 2, wherein said space diversity transmission scheme is a selective transmitter antenna diversity scheme.

4. A method according to any one of the proceeding claims, wherein said second diversity transmission scheme is a frequency or time diversity scheme.

5. A method according to claim 4, wherein said second diversity transmission scheme is a complex diversity transform scheme.

6. A method according to claim 5, wherein said complex diversity transform scheme comprises an orthonormal

transformation to a constellation which preserves Euclidean distances but improves the resistances to fading.

7. A method according to claim 5 or 6, wherein an original signal constellation represented as a matrix is used, and wherein each row of said matrix corresponds to a point in a multidimensional constellation.

8. A method according to claim 6 or 7, wherein said orthonormal transformation is achieved by a multiplication with a complex matrix.

9. A method according to claim 8, wherein each row of said complex matrix is orthogonal to any other row, and wherein the determinant of said matrix is equal to one.

10. A method according to claim 8 or 9, wherein said complex matrix is obtained based on an upperbound on the symbol error rate or based on a cutoff rate.

11. A method according to any one of claims 1 to 10, wherein said diversity transmission method is used in a downlink transmission of a cellular network.

12. A method according to any one of the preceding claims, wherein said transmission signal is a bit stream and said plurality of subsignals are substreams.

13. A method according to claim 12, wherein said transmission signal is a QPSK signal which can be represented by a vertex in a 2M-dimensional hyper-cube, where M denotes the dimension of a signal constellation.

14. A method according to any one of the preceding claims, wherein said wireless communication system is a WCDMA system.

15. A method according to any one of the preceding claims, wherein said first and second diversity transmission schemes comprise an open loop and/or a closed loop system.

16. A method according to any one of the preceding claims, wherein time slots of frequency carriers used in said second diversity transmission scheme are spaced apart to such a degree that independent fading is assured.

17. A method according to any one of the preceding claims, wherein said transmission signal comprises a signal constellation generated by optimizing the bit error rate and the peak to average ratio for a Rayleigh fading channel.

18. A transmitter for a diversity transmission system for transmitting a transmission signal in a wireless communication system, comprising:

a) dividing means **(10)** for dividing said transmission signal into a plurality of subsignals;

b) transforming means **(11)** for applying an orthonormal transformation to said plurality of subsignals; and

c) transmitting means **(12)** for transmitting a first set of said subsignals using a first diversity transmission scheme, and a second set of said subsignals using a second diversity transmission scheme different from said first diversity transmission scheme.

19. A transmitter according to claim 18, wherein said first diversity transmission scheme is a space diversity transmission scheme using a plurality of transmission antennas **(A1-AM)**.

20. A transmitter according to claim 18 or 19, wherein said second diversity transmission scheme is a time or frequency diversity transmission scheme using a plurality of time slots or carrier frequencies.

21. A transmitter according to any one of claims 18 to 20, wherein said transforming means comprises a complex diversity transformation unit **(11)** arranged for performing an orthonormal transformation to a constellation which preserves Euclidean distances but improves resistance to fading of an original signal constellation obtained from said dividing means **(10)**.

22. A transmitter according to any one of claims 18 to 21, wherein said transmitter is arranged in a WCDMA base station.

23. A receiver for a diversity transmission system, for receiving a transmission signal in a wireless communication system, comprising:

a) receiving means **(40, 4110, 4111, 4120, 4121, 41M0, 41M1, 421, 422,...42M)** for receiving a transmission signal comprising a first set of subsignals transmitted by using a first diversity transmission scheme, and a second set of subsignals transmitted by using a second diversity transmission scheme different from said first diversity transmission scheme; and

b) decoding means **(43)** for decoding said transmission signal by deciding on a maximum likelihood between said received subsignals and corresponding estimated subsignals.

24. A receiver according to claim 23, further comprising channel estimation means **(44)** for performing a channel estimation used for obtaining said corresponding estimated subsignals.

25. A receiver according to claim 23 or 24, wherein said first diversity transmission scheme is a space diversity transmission scheme.

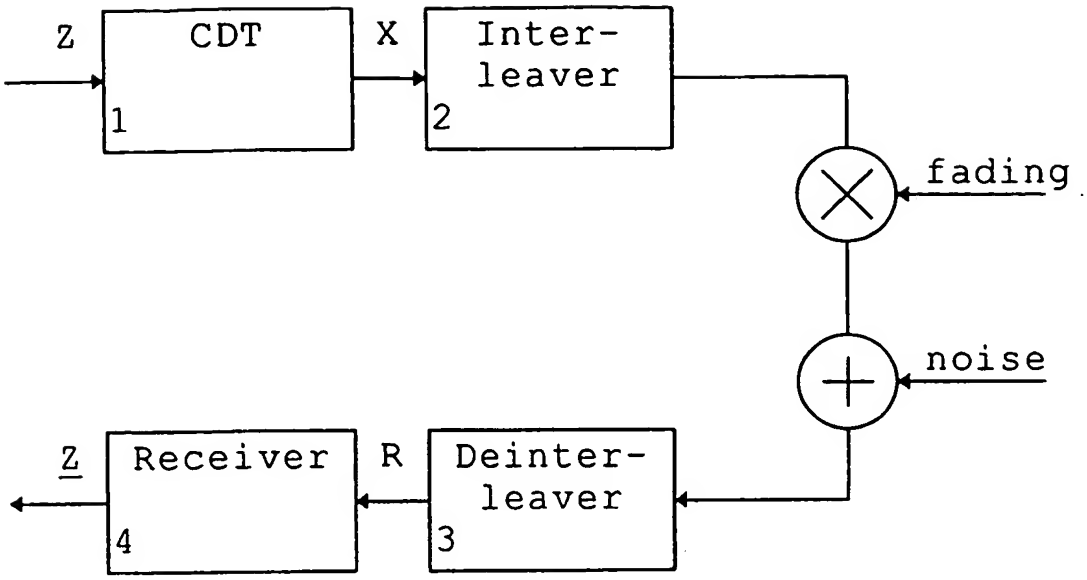
26. A receiver according to claim 25, wherein said space diversity transmission scheme is a selective transmitter antenna diversity scheme.

27. A receiver according to any one of claims 23 to 26, wherein said second diversity scheme is a time or frequency diversity scheme.

28. A receiver according to claim 27, wherein said time or frequency diversity scheme is a complex diversity transformation scheme.

29. A receiver according to any one of claims 23 to 28, wherein said transmission signal is a QPSK signal and said receiving means comprises a bank of 2M correlators, wherein M denotes the number of transmission antennas used in said first diversity transmission scheme.

30. A receiver according to any one of claims 23 to 29, wherein said receiver is arranged in a mobile WCDMA terminal of a cellular network.


Z
CDT
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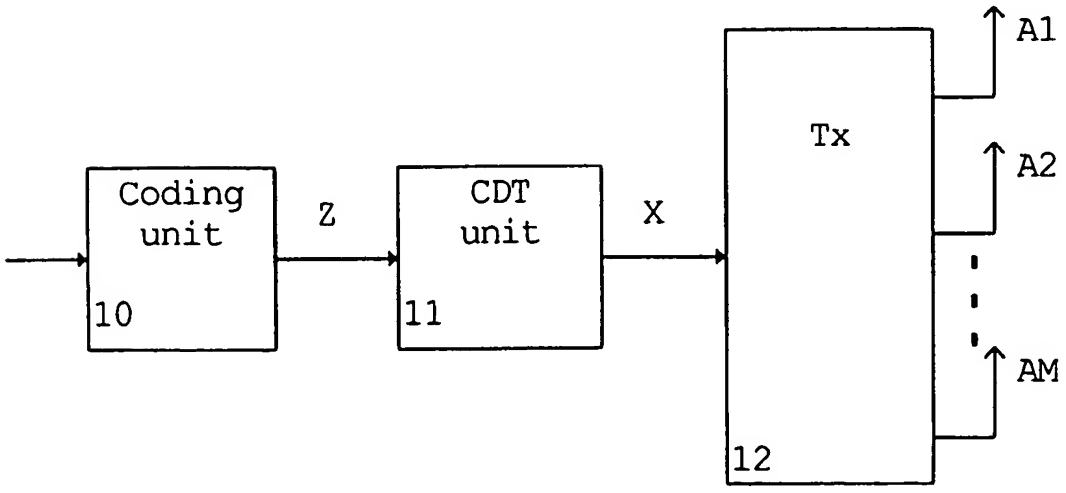
X
Inter-
leaver
2
fading
noise
Z
Receiver
4
R
Deinter-
leaver
3

Fig. 1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unit
10
Z
CDT
unit
11
X
Tx
12
A1
A2
AM

Fig. 2

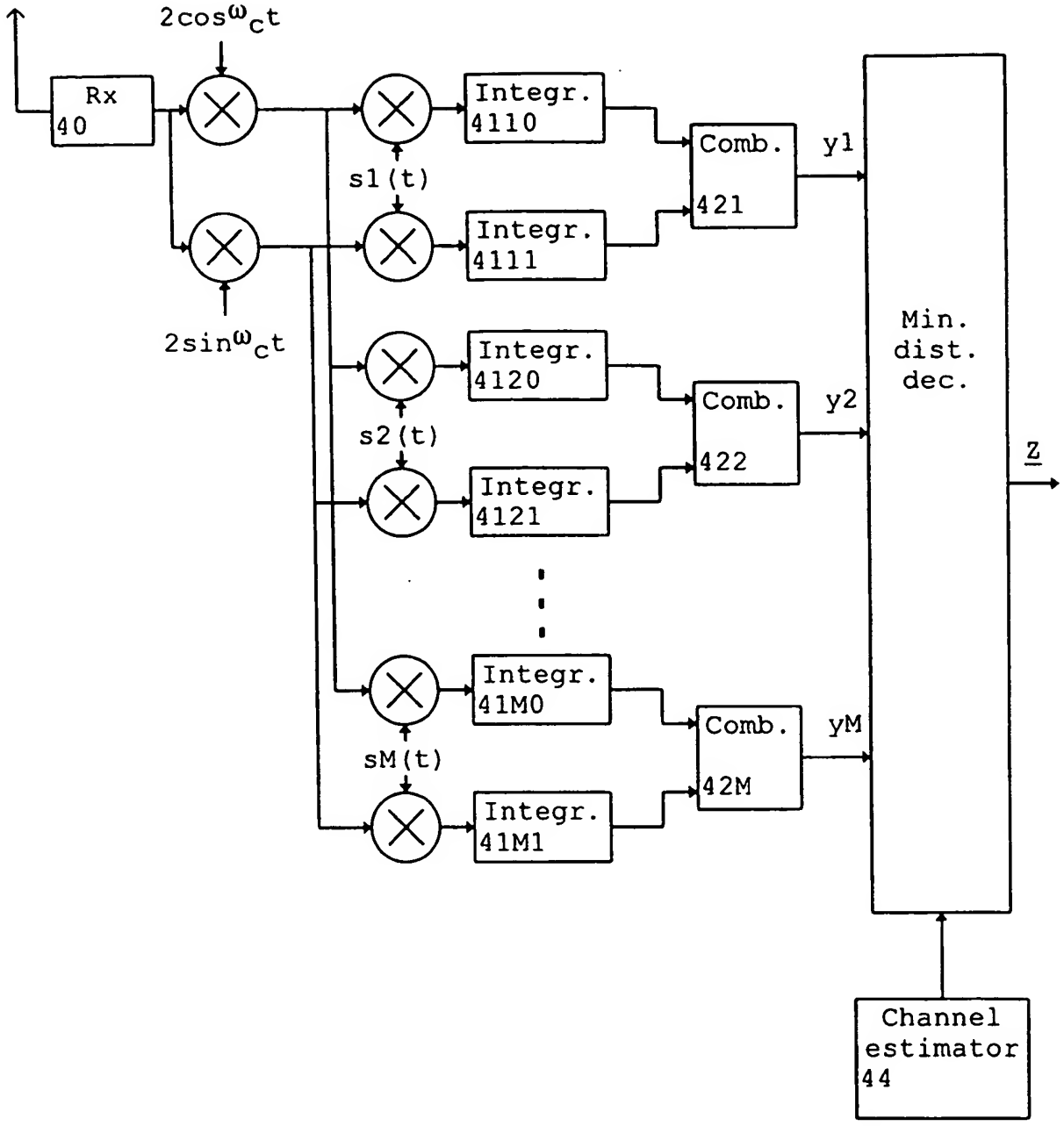
2cosω_ct
Rx
40
Integr.
4110
s1(t)
Integr.
4111
2sinω_ct
Comb.
421
y1
Integr.
4120
s2(t)
Integr.
4121
Comb.
422
y2
Min.
dist.
dec.
z
Integr.
41M0
sM(t)
Integr.
41M1
Comb.
42M
yM
Channel
estimator
44

Fig. 3

INTERNATIONAL SEARCH REPORT

Inter. nal Application No
PCT/EP 99/04237

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/06 H04L1/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 832 044 A (SOUSA ELVINO S ET AL) 3 November 1998 (1998-11-03) cited in the application column 3, line 18 -column 4, line 33 column 5, line 1 - line 50 column 6, line 25 -column 11, line 19	1-4, 11-20, 22-27, 29,30
A	column 13, line 14 -column 14, line 29	5-9,21, 28

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 March 2000	16/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lõpez-Pérez, M-C

INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/EP 99/04237

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DASILVA V M ET AL: "FADING-RESISTANT MODULATION USING SEVERAL TRANSMITTER ANTENNAS" IEEE TRANSACTIONS ON COMMUNICATIONS,US,IEEE INC. NEW YORK, vol. 45, no. 10, 1 October 1997 (1997-10-01), pages 1236-1244, XP000723121 ISSN: 0090-6778 cited in the application page 1236, left-hand column, line 18 -page 1240, left-hand column, line 14	1,4-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. ...nal Application No
PCT/EP 99/04237

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5832044 A	03-11-1998	NONE	